

Air Emissions and Wood Boilers

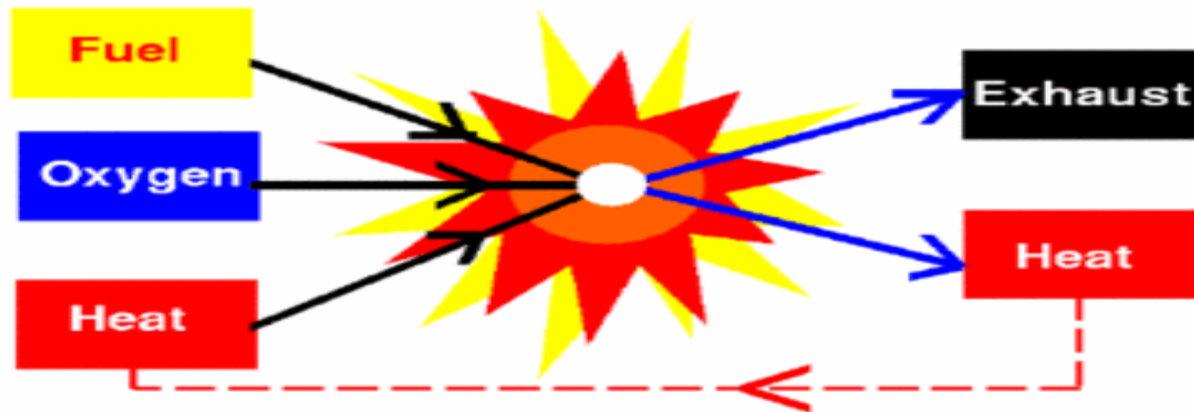
Stack Test Results, Optimizing Combustion and Minimizing Emissions

Presented by:
Calvin W. Loomis, PE, QSTI
Bison Engineering Inc.
Process and Emissions Services Team Leader

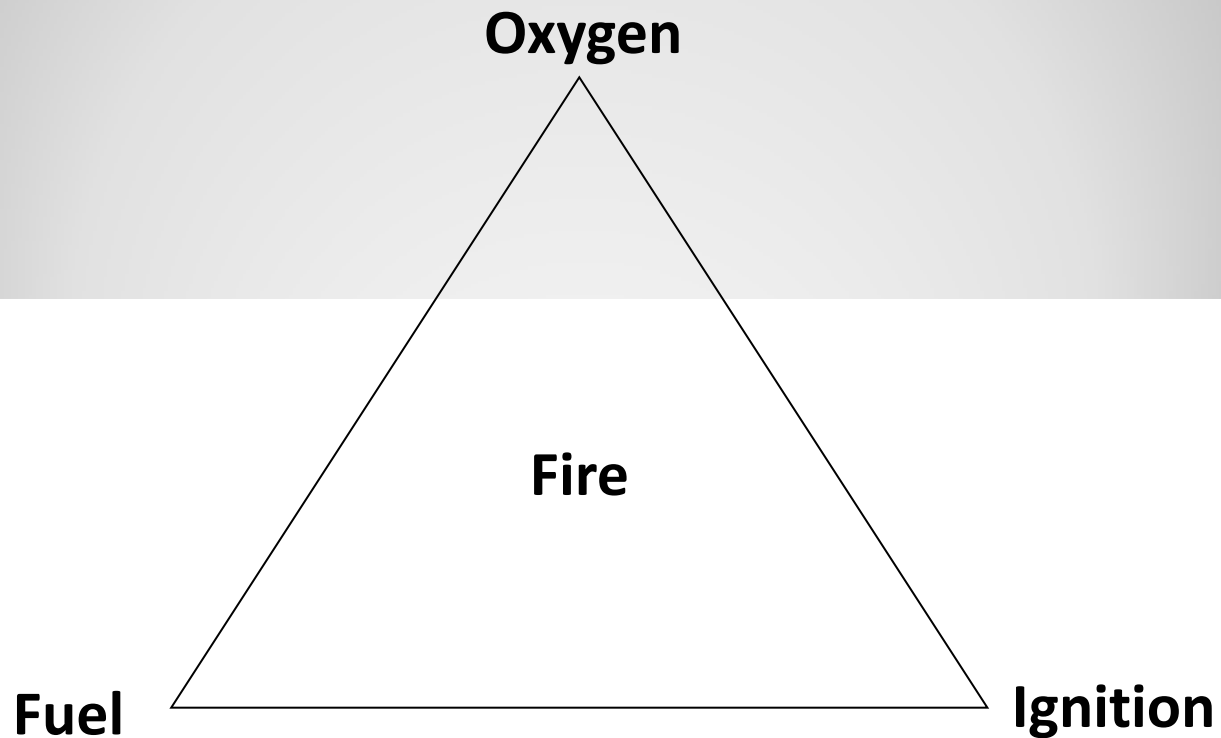
Biomass Boiler Operator's Summit
August 9, 2011

Combustion

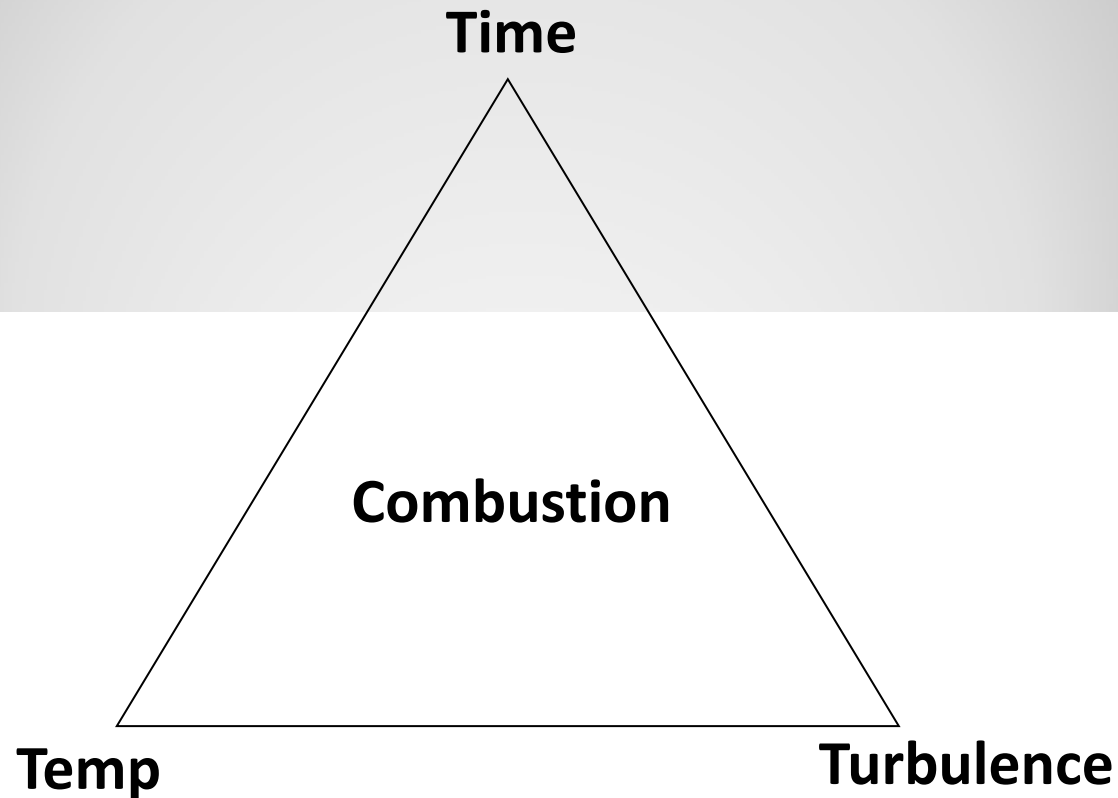
Combustion (burning) is the sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat and conversion of chemical species. The release of heat can result in the production of light in the form of either glowing or a flame.



The Fire Triangle



The Three T's of Combustion



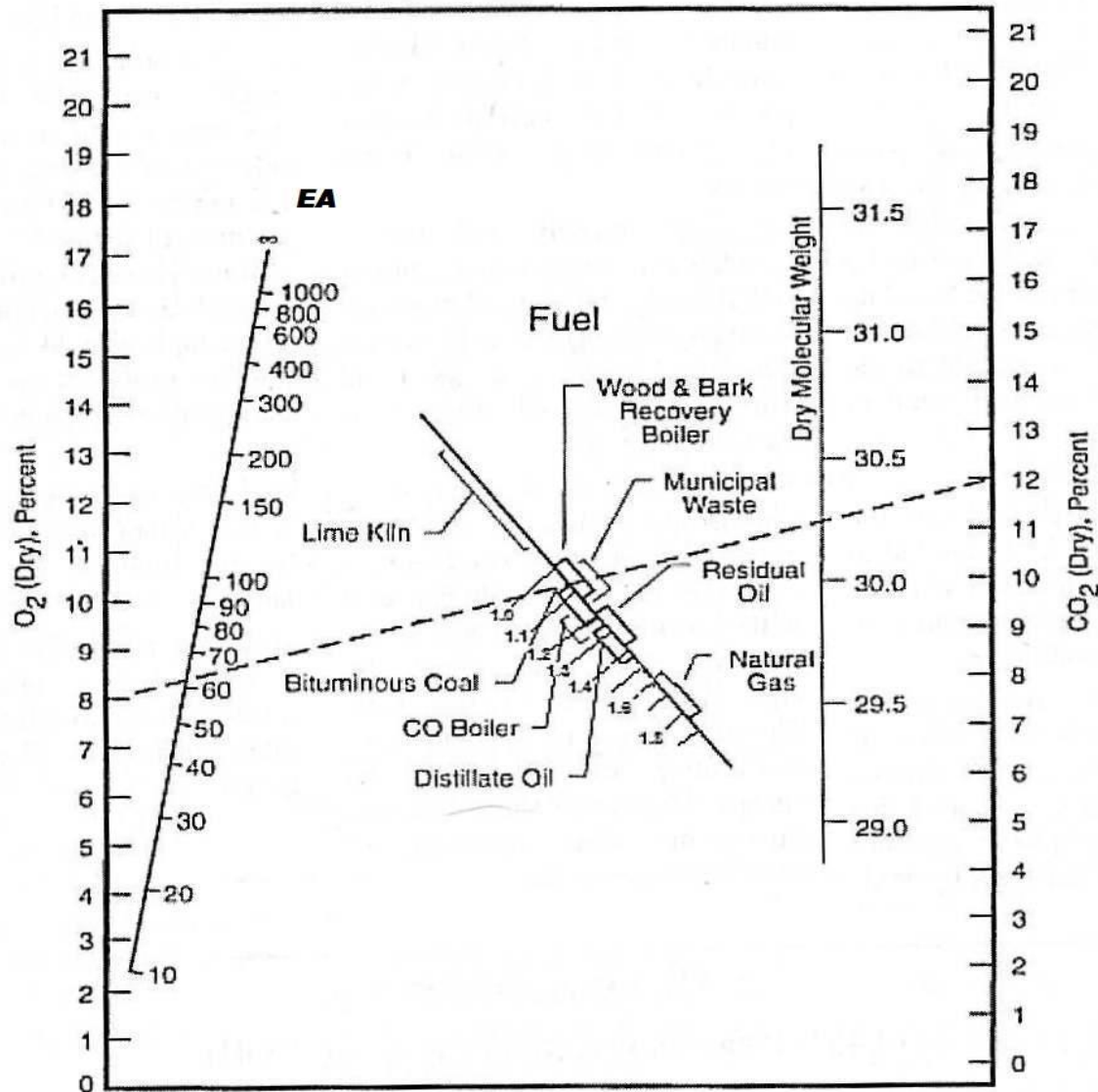
Oxygen and Excess Air

Available O₂ = 21% for basic combustion

Exhaust O₂ = pending combustion parameters

Excess Air = O₂ needed for complete combustion

Oxygen and Excess Air



Fuel Type	F _O Range
Coal	
Anthracite and Lignite	1.016 - 1.130
Bituminous	1.083 - 1.230
Oil	
Distillate	1.260 - 1.413
Residual	1.210 - 1.370
Gas	
Natural	1.600 - 1.836
Propane	1.434 - 1.586
Butane	1.405 - 1.553
Wood	1.000 - 1.120
Wood Bark	1.003 - 1.130

Combustion Exhaust

Products of Combustion (POCs)

H₂O, NO_x, CO₂, PM

Products of Incomplete Combustion (PICs)

CO, PM

Pass-through Pollutants

SO₂, Metals

Products of Zero Oxygen Combustion

(Pyritic Combustion)

Dioxins

Complete and Incomplete Combustion

Complete Combustion

Carbon/hydrogen (fuel) + O₂ \longrightarrow H₂O + CO₂ + O₂ (excess air)

Incomplete Combustion

Carbon/hydrogen fuel + O₂ \longrightarrow H₂O + CO₂ + CO + O₂

Heat from Combustion

Available Heat = usable heat

Latent Heat = heat used to vaporize H₂O

The Pollutants from Combustion

CO = PIC = odorless, tasteless and toxic

NO_x = POC = NO, NO₂, NO₃, ...

Fuel NO_x vs. Thermal NO_x

PM = POC & PIC = PM, PM₁₀, PM_{2.5}, CPM

CO₂ = POC = Greenhouse gas

Combustion Control of the Pollutants from Combustion

CO = PIC = better balance on the Thee T's

NOx = POC = formed from the peak flame temp.

PM = POC & PIC = better 3-T balance

Boiler Fans for Combustion

FD fans – forced draft fans pushes

ID fans – Induced draft + chimney effect pulls

OD fans – Overdraft fans “secondary air”

UD fans – under draft fans “primary air”

Mixing fans – blowers to improve chamber mixing

The fuel factor

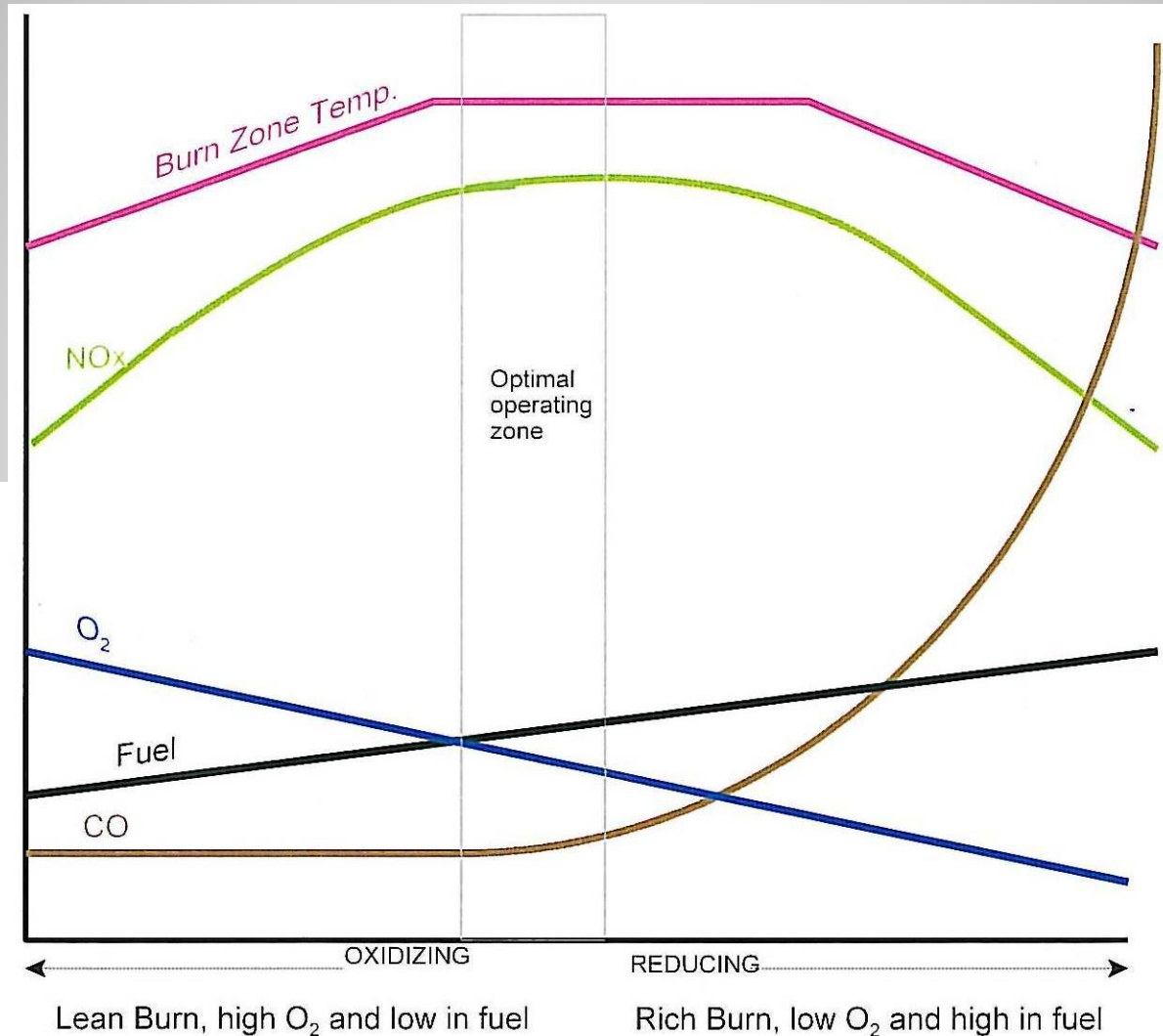
Reduce latent heat loss with dry fuel.

Reduce combustion time with smaller fuel particles.

Improvements with the 3 T's

Darby School							
Boiler Emissions		LOW FIRE			HIGH FIRE		
Stack Information		2008	2011	% Change	2008	2011	% Change
avg stack temp [ts]	Deg. F	331	244	-26%	334	334	0%
actual stack flow	acfm	1000	567	-43%	1962	1183	-40%
actual stack velocity [Vs]	ft/sec	8	4	-43%	15	9	-40%
Standard stack flow per min	dscfm	533	338	-37%	930	585	-37%
Standard stack flow per hr	dscf/hr	31961	20292	-37%	55801	35746	-36%
Oxygen content	%O2	10.0	4.8	-52%	12.3	4.8	-61%
Grain loading Emissions		2008	2011	% Change	2008	2011	% Change
PM2.5	gr/dscf	0.0444	0.0234	-47%	0.0279	0.0417	50%
Total PM	gr/dscf	0.0819	0.0403	-51%	0.0531	0.0867	63%
Mass Rate Emissions		2008	2011	% Change	2008	2011	% Change
PM2.5	lbs/hr	0.2020	0.0678	-66%	0.2227	0.2064	-7%
Total PM	lbs/hr	0.3736	0.1168	-69%	0.4251	0.4339	2%
Emission Factor		2008	2011	% Change	2008	2011	% Change
PM2.5	lbs/MMBtu	0.1144	0.0408	-64%	0.0905	0.0727	-20%
Total PM	lbs/MMBtu	0.2116	0.0690	-67%	0.1723	0.1496	-13%
Gaseous emissions		2008	2011	% Change	2008	2011	% Change
NOx	ppmvd	53	50	-5%	51	55	7%
NOx	lbs/hr	0.2002	0.1212	-39%	0.3421	0.2304	-33%
NOx	lbs/MMBtu	0.1134	0.0729	-36%	0.1390	0.0802	-42%
CO	ppmvd	168	31	-82%	185	254	37%
CO	lbs/hr	0.3900	0.0457	-88%	0.7498	0.6477	-14%
CO	lbs/MMBtu	0.2208	0.0275	-88%	0.3093	0.2253	-27%
Boiler operating rate		2008	2011	% Change	2008	2011	% Change
Boiler operating rate	MMBtu/hr	1.77	1.66	-6%	2.46	2.90	18%

Basic Combustion



Questions

**Cal Loomis, PE, QSTI
Bison Engineering
Helena, MT**

406.442.5768